Status of the KEK Super B Factory

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(for the “SuperBelle” collaboration)

Outline of the talk:

- Motivation
- Requirements
- Design and progress
- Summary

DISCRETE`08, 11th - 16th December 2008, Valencia
- e\(^-\) (8 GeV) on e\(^+\) (3.5 GeV)
  - \(\sqrt{s} \approx m_{\Upsilon(4S)}\)
  - Lorentz boost: \(\beta \gamma = 0.425\)
- 22 mrad crossing angle
- Operating since 1999

Peak luminosity (WR1) :
\[1.71 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}\]
The KEKB performance

Luminosity Records:

- Peak $L = 1.71 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ (70% above the design value)
- Daily $\int L \, dt = 1232 \text{ pb}^{-1}$ (2x the design value)
- Total $\int L \, dt = 887 \text{ fb}^{-1}$ (as of 9th December 2008)

The best daily luminosity

Continuous injection

$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
B- Factories (KEKB&PEP-II): A Success Story

Discovery of CP violation in the B system

Measurements of the CKM matrix elements

\[ B^0 \rightarrow J/\psi K^0 \]

\[ \bar{B}^0 \rightarrow J/\psi K^0 \]

Asymmetry = (N-N)/(N+N)

PDG 2008
“… As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.”
**B- Factories (KEKB&PEP-II):**

*Other achievements*

- **Many new resonances**
  - $A_{FB}$ in $B \rightarrow K^* l^+ l^-$
  - Signal
  - Evidence for $B \rightarrow \tau \nu$
  - Limits on charged Higgs
  - $D^0 - \overline{D^0}$ mixing
  - Evidence for $B \rightarrow K^* l^+ l^-$
  - $b \rightarrow d \gamma$ transition
  - Evidence for $B \rightarrow \tau \nu$

- $y_{CP} = 1.31 \pm 0.32 \pm 0.25\%$

Marko Bračko

DISCRETE '08, Valencia
Physics at a Super B Factory

• What is the next experimental step? Precision measurements
  • Much larger sample needed for this purpose → Super B factory

• Hopefully new phenomena might be seen:
  – CPV in B decays from the physics outside the KM scheme.
  – Lepton flavor violations in $\tau$ decays.

• Physics models can be identified (if new effects are observed)
  or new ones can be constrained (if nothing is seen).

• Even in the worst case scenario (e.g. for MFV), $B \rightarrow \tau\nu$, $D_{\tau\nu}$ can
  probe the charged Higgs in the large $\tan\beta$ region.

• Physics motivation is independent of LHC.
  – If LHC finds NP, precision flavour physics is compulsory.
  – If LHC finds no NP, high statistics $B/\tau$ decays would be a unique
    way to search for the TeV scale physics.
### Physics reach at a Super KEKB/Belle

<table>
<thead>
<tr>
<th></th>
<th>Belle’06 (~0.5ab⁻¹)</th>
<th>5ab⁻¹</th>
<th>50ab⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta S(\phi K^0) )</td>
<td>0.22</td>
<td>0.073</td>
<td>0.029</td>
</tr>
<tr>
<td>( \Delta S(\eta' K^0) )</td>
<td>0.11</td>
<td>0.038</td>
<td>0.020</td>
</tr>
<tr>
<td>( \Delta S(K_S K_S K_S) )</td>
<td>0.33</td>
<td>0.105</td>
<td>0.037</td>
</tr>
<tr>
<td>( \Delta S(K_S \pi^0 \gamma) )</td>
<td>0.32</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>( \text{Br}(X_{s\gamma}) )</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( A_{CP}(X_{s\gamma}) )</td>
<td>0.058</td>
<td>0.01</td>
<td>0.005</td>
</tr>
<tr>
<td>( C_9 [A_{FB}(K^{*-})] )</td>
<td>---</td>
<td>11%</td>
<td>4%</td>
</tr>
<tr>
<td>( C_{10} [A_{FB}(K^{*-})] )</td>
<td>---</td>
<td>13%</td>
<td>4%</td>
</tr>
<tr>
<td>( \text{Br}(B^* \to K^{*-}\nu\nu) )</td>
<td>&lt;9Br(SM)</td>
<td>33ab⁻¹ for 5σ discovery</td>
<td></td>
</tr>
<tr>
<td>( \text{Br}(B^* \to \tau\nu) )</td>
<td>3.5σ</td>
<td>10%</td>
<td>3%</td>
</tr>
<tr>
<td>( \text{Br}(B^* \to \mu\nu) )</td>
<td>&lt;2.4Br(SM)</td>
<td>4.3ab⁻¹ for 5σ discovery</td>
<td></td>
</tr>
<tr>
<td>( \text{Br}(B^* \to D\tau\nu) )</td>
<td>---</td>
<td>7.9%</td>
<td>2.5%</td>
</tr>
<tr>
<td>( \text{Br}(\tau \to \mu\gamma) )</td>
<td>&lt;45</td>
<td>&lt;30</td>
<td>&lt;8</td>
</tr>
<tr>
<td>( \text{Br}(\tau \to \mu\eta) )</td>
<td>&lt;65</td>
<td>&lt;20</td>
<td>&lt;4</td>
</tr>
<tr>
<td>( \text{Br}(\tau \to 3\mu) )</td>
<td>&lt;209</td>
<td>&lt;10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>( \Delta \sin^2 \phi_1 )</td>
<td>0.026</td>
<td>0.016</td>
<td>0.012</td>
</tr>
<tr>
<td>( \Delta \Phi_2 (\rho \pi) )</td>
<td>68°—95°</td>
<td>3°</td>
<td>1°</td>
</tr>
<tr>
<td>( \Delta \Phi_3 \text{ (Dalitz)} )</td>
<td>20°</td>
<td>7°</td>
<td>2.5°</td>
</tr>
<tr>
<td>( \Delta V_{ub} \text{ (incl.)} )</td>
<td>7.3%</td>
<td>6.6%</td>
<td>6.1%</td>
</tr>
</tbody>
</table>

#### Upper limits

- \( \text{Br}(B^* \to \tau\nu) \) at 50ab⁻¹: 3.5σ discovery
- \( \text{Br}(B^* \to \mu\nu) \) at 50ab⁻¹: 2.4Br(SM)

#### CP asymmetry

- Present exp. limits on \( B \to KKK, \phi K \) and \( \eta' K \)

#### Search for \( H^\pm \) in \( B \to \tau\nu \)

50ab⁻¹ assume 5σ discovery

#### Physics at Super B Factory

- [hep-ex/0406071](https://arxiv.org/abs/hep-ex/0406071)

Currently being updated.
What should the peak luminosity be?
How to do it? Upgrade KEKB & Belle
KEKB upgrade: Super B Factory at KEK

- Asymmetric energy $e^+e^-$ collider at $E_{CM}=m(Y(4S))$ to be realized by upgrading the existing KEKB collider. 
- **Initial target:** $10 \times$ higher luminosity $\equiv 2 \times 10^{35}$/cm$^2$/sec
  $\rightarrow 2 \times 10^9 \ B\bar{B} $ and $\tau^+\tau^-$ per year.
- **Final goal:** $L=8 \times 10^{35}$/cm$^2$/sec and $\int L \ dt = 50 \ ab^{-1}$
# Major KEKB components: Cost & effects

<table>
<thead>
<tr>
<th>Item</th>
<th>Object</th>
<th>Oku-yen ~1.0 M$</th>
<th>Luminosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>New beam pipes</td>
<td>Enable high current</td>
<td>178 (incl. BPM, magnets, etc.)</td>
<td>x 1.5</td>
</tr>
<tr>
<td></td>
<td>Reduce e-cloud</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New IR</td>
<td>Small $\beta^*$</td>
<td>31</td>
<td>x 2</td>
</tr>
<tr>
<td>e+ Damping Ring</td>
<td>Allow injection with small increase e+ capture</td>
<td>40 incl. linac upgrade</td>
<td>if not, x 0.75</td>
</tr>
<tr>
<td>More RF and cooling systems</td>
<td>High current</td>
<td>179 (incl. facilities)</td>
<td>x 3</td>
</tr>
<tr>
<td>Crab Cavities</td>
<td>Higher beam-beam param.</td>
<td>15</td>
<td>x (2 – 4)</td>
</tr>
</tbody>
</table>

Items are interrelated.

- Tunnel already exists.
- Most of the components (magnets, klystrons, etc.) will be re-used.
Crab cavities

Crab cavities

Installed in the tunnel (Feb. 2007)
Under commissioning…
Ante-chamber /solenoid for reduction of electron clouds

Ante-chamber with solenoid field
Requirements for the Super B detector

Critical issues at $L = 8 \times 10^{35}/\text{cm}^2/\text{sec}$

- **Higher background ($\times 20$)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM

- **Higher event rate ($\times 10$)**
  - higher rate trigger, DAQ and computing

- **Require special features**
  - low $p_{\mu}$ identification $\rightarrow s_{\mu\mu}$ recon. eff.
  - hermeticity $\rightarrow \nu$ “reconstruction”

Possible solution:

- Replace inner layers of the vertex detector with a silicon striplet or pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing system.
Belle upgrade for the Super B Factory

SC solenoid 1.5T

CsI(Tl) 16\(X_0\) → pure CsI (endcap)

Aerogel Cherenkov counter + TOF counter → “TOP” + Aerogel RICH

\(\mu/K_L\) detection 14/15 lyr. RPC+Fe → tile scintillator

Tracking + \(dE/dx\) small cell + He/C\(_2\)H\(_6\) remove inner lysrs. fast gas+Si \(r<20\) cm

Si vtx. det. 4 lyr. DSSD → 2 pixel/striplet lysrs. + 4 lyr. DSSD

New readout and computing systems

“sBelle Detector Study Report” posted as arXiv: 0810.4084

Neuraw
• Readout chip: VA1TA → APV25
  - Reduction of occupancy coming from beam background.
  - Pipeline readout to reduce dead time.
• Sensors of the innermost layer:
  Normal double sided Si detector (DSSD) → Pixel sensors
• Configuration: 4 layers → 6 layers
  (outer radius = 8cm → 14cm)
  - More robust tracking
  - Higher Ks vertex reconstruction efficiency
• Inner radius: 1.5cm → 1.0cm
  - Better vertex resolution. Not on day 1.
CDC upgrade

- Larger outer radius:
  - 752mm → 978mm
  - Longer lever arm → better $P_t$ reso.
  - More samplings → better $dE/dx$ reso.
- Smaller cell size:
  - 12mm, 64cells → 8mm, 160cells
  - Improved background tolerance
- New ASD with fast shaping
Barrel PID: Time of propagation (TOP) counter

- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from one coordinate and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution < ~ 40 ps
    - Single photon sensitive under 1.5 T
• Proximity focusing RICH with aerogel radiator

Highly transparent aerogel: $\Lambda_t > 40 \text{mm} (\lambda=400\text{nm})$

Multi-pixel photodetector to measure single photon positions in $B=1.5\text{T}$
→ Hybrid Avalanche PhotoDiode
→ Micro Channel Plate - PMT
→ Geiger mode Avalanche PhotoDiode
- Increase of dark currents due to neutron flux
- Fake clusters & pile-up noise

**Barrel:**
0.5\(\mu\)s shaping + 2MHz w.f. sampling.

**Endcap:**
pure CsI + photopentods
30ns shaping + 43MHz w.f. sampling
Scintillator-based KLM (endcap)

- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photo-detector = avalanche photodiode in Geiger mode (SiPM)
- ~120 strips in one 90º sector
  (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%

**KLM upgrade**

- Mirror 3M (above groove & at fiber end)
- Optical glue increase the light yield ~ 1.2-1.4
- **WLS:** Kurarai Y11 $\varnothing$1.2 mm
- **GAPD**
- **Diffusion reflector (TiO$_2$)**
- **Strips:** polystyrene with 1.5% PTP & 0.01% POPOP
Effective background with new hardwares

<table>
<thead>
<tr>
<th>How</th>
<th>Reduction factor</th>
<th>Effective bkg</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVD Shorter $t_p$</td>
<td>$50/800=1/16=1/12.5$</td>
<td>0 ~ 1</td>
</tr>
<tr>
<td>CDC Smaller cell</td>
<td>&lt;2/3</td>
<td>4 ~ 13 (*)</td>
</tr>
<tr>
<td>PID Brand new device</td>
<td>Good enough</td>
<td>0 ~ 1</td>
</tr>
<tr>
<td>B-ECL Waveform fitting</td>
<td>1/7</td>
<td>1 ~ 2</td>
</tr>
<tr>
<td>E-ECL Pure CsI (shorter t)</td>
<td>1/200</td>
<td>0 ~ 1</td>
</tr>
<tr>
<td>KLM Faster detector, finer segment</td>
<td>Under control</td>
<td>0 ~ 1</td>
</tr>
</tbody>
</table>

(*) Software efforts needed for CDC

Background effects on tracking

Gain in reconstruction efficiency of $B \rightarrow D^*D^*(D^* \rightarrow D_\pi^0, D \rightarrow K_3^\pi)$

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Present Belle</th>
<th>Software update</th>
<th>+SVD tracker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>$\varepsilon=4.3%$</td>
<td>$\varepsilon=7.1%$ (+65%)</td>
<td>$\varepsilon=11.9%$ (+177%)</td>
</tr>
<tr>
<td>$\times5$ BG</td>
<td>$\varepsilon=6.3%$ (+47%)</td>
<td>$\varepsilon=11.2%$ (+160%)</td>
<td></td>
</tr>
<tr>
<td>$\times20$ BG</td>
<td>$\varepsilon=3.8%$ (−12%)</td>
<td>$\varepsilon=8.8%$ (+105%)</td>
<td></td>
</tr>
</tbody>
</table>

“sBelle Detector Study Report” posted as arXiv: 0810.4084
KEK’s 5-year roadmap.

3-year shutdown for KEKB upgrade
- 0.5-1 year delay, KEKB will run in FY2009

KEK management is in close contact with MEXT (Japanese Ministry of Education, Culture, Sports, Science and Technology).
- “Investigation money” requested in FY2008.

We also hope for the positive effects from the Nobel Prize …
Luminosity prospects

Results from Super-Belle @ ~10ab⁻¹
LHC(b)
Situation of LC...

3-year shutdown for upgrade

10ab⁻¹ (initial target) ~ 2016

L~8x10^{35} cm⁻²s⁻¹

50ab⁻¹ by ~2020

L~2x10^{35} cm⁻²s⁻¹
Super Belle will be a new international collaboration.
- Two proto-collaboration meetings in Mar&Jul, 2008
  - Participation of new people from Germany, India, U.S., Japan,….
- Kick-off of the new collaboration: 10\textsuperscript{th}-12\textsuperscript{th} Dec 2008.
  - Still most of the sessions were be open.

Near-term plan (preliminary)
- Detector study report has been completed.
- Detector proposals (by summer 2009).
- The final detector design by Dec. 2009.

Super-Belle webpage
http://superb.kek.jp/
Mailing list subscription is available.
Summary

- B factories have proven to be an excellent tool for flavour physics.
- Reliable long term operation, constant improvement of the performance.
- Major upgrade of KEKB and Belle in 2009-2012
  -> Super B factory; Luminosity: x10 -> x40
- Essentially this is a new project, all components have to be replaced; Plans exist (LoI 2004 - KEK Report 04-4; sBelle Design Study Report 2008 - arXiv: 0810.4084), nothing is frozen...
  ... expect a new, exciting era of discoveries, complementary to LHC...
  ... You could be a part of it, since:

  **New groups and individuals are highly welcome.**
Supplementary material
The Belle spectrometer at the KEK-B

μ and K_L detection system
(14/15 layers RPC+Fe)

Silicon Vertex Detector
(4 layers DSSD)

Aerogel Cherenkov Counter
(n=1.015-1.030)

Electromag. Cal.
(Csl crystals, 16X_0)

Central Drift Chamber
(small cells, He/C_2H_6)

ToF counter

8 GeV e^-

3.5 GeV e^+

1.5T SC solenoid
Super B factory: An important part of a broad unbiased approach to New Physics

- LHC, ILC
  - Mass spectrum, interactions
- Energy frontier
- Lepton sector
  - \( \nu \) experiments, \( g_\mu -2, \mu \rightarrow e \), etc.
- \( \nu \) mass and mixing, CPV, and LFV
- Quark sector
  - \( \tau \) LFV, \( \tau \) CPV
  - Flavor mixing, CP phases
- Super B factory, LHCb, K experiments…
### Comparison with the LHCb

<table>
<thead>
<tr>
<th>$e^+e^-$ has advantages in...</th>
<th>LHCb has advantages in...</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPV in $B \rightarrow \phi K_S, \eta' K_S$,...</td>
<td>CPV in $B \rightarrow J/\psi K_S$</td>
</tr>
<tr>
<td>CPV in $B \rightarrow K_S \pi^0 \gamma$</td>
<td>Most of $B$ decays not including $\nu$ or $\gamma$</td>
</tr>
<tr>
<td>$B \rightarrow K \nu \nu, \tau \nu, D(*) \tau \nu$</td>
<td>Time dependent measurements of $B_S$</td>
</tr>
<tr>
<td>Inclusive $b \rightarrow s \mu \mu$, see</td>
<td>$B_{(s,d)} \rightarrow \mu \mu$</td>
</tr>
<tr>
<td>$\tau \rightarrow \mu \gamma$ and other LFV</td>
<td>$B_c$ and bottomed baryons</td>
</tr>
<tr>
<td>$D^0 \bar{D}^0$ mixing</td>
<td>Complementary!!</td>
</tr>
</tbody>
</table>
How to achieve a very high luminosity?

Luminosity:
- $0.17 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (KEKB)
- $5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (SuperKEKB)

Stored current:
- $1.7 / 1.4 \text{ A (e}^+ / \text{ e}^- \text{ KEKB)}$
- $\rightarrow 9.4 / 4.1 \text{ A (SuperKEKB)}$

Beam-beam parameter:
- $0.059$ (KEKB)
- $\rightarrow >0.24$ (SuperKEKB)

Vertical $\beta$ at the IP:
- $6.5 / 5.9 \text{ mm (KEKB)}$
- $\rightarrow 3.0 / 3.0 \text{ mm (SuperKEKB)}$

Lorentz factor
\[
L = \frac{\gamma^\pm}{2e\varepsilon_r} \left( 1 + \frac{\sigma_y^*}{\sigma_x^*} \right) I^\pm \xi_{\pm y} \frac{R_L}{R_y} \beta_y^*
\]

Classical electron radius

Beam size ratio

Geometrical reduction factors due to crossing angle and hour-glass effect

Crab cavity
### Luminosity gain and upgrade items (preliminary)

<table>
<thead>
<tr>
<th>Item</th>
<th>Gain</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam pipe</td>
<td>x 1.5</td>
<td>high current, short bunch, electron cloud</td>
</tr>
<tr>
<td>IR((\beta_{x/y}^*=20\text{cm/3}\text{mm})</td>
<td>x 1.5</td>
<td>small beam size at IP</td>
</tr>
<tr>
<td>low emittance(12 nm) (\nu_x \to 0.5)</td>
<td>x 1.3</td>
<td>mitigate nonlinear effects with beam-beam</td>
</tr>
<tr>
<td>crab crossing</td>
<td>x 2</td>
<td>mitigate nonlinear effects with beam-beam</td>
</tr>
<tr>
<td>RF/infrastructure</td>
<td>x 3</td>
<td>high current</td>
</tr>
<tr>
<td>DR/e(^+) source</td>
<td>x 1.5</td>
<td>low (\beta^*) injection, improve e(^+) injection</td>
</tr>
<tr>
<td>charge switch</td>
<td>x ?</td>
<td>electron cloud, lower e(^+) current</td>
</tr>
</tbody>
</table>
As of autumn 2008

KEKB track record

Integrated Luminosity (log)

KEKB + PEP-II

KEKB for Belle

PEP-II for BaBar

\[ L_{\text{peak}} (\text{KEKB}) = 1.7 \times 10^{34} / \text{cm}^2 / \text{sec} \text{ (design 1.0)} \]

~ 1.5 Billion \( B \bar{B} \) pairs

~ 1.4 ab\(^{-1}\)
Crab cavity commissioning

Crab Crossing
- 49 sp. \( \beta x^* = 80, 84 \text{cm} \)
- \( \beta x^* = 80 \text{cm} \)
- \( \beta x^* = 90 \text{cm} \)
- \( \beta x^* = 68 \text{cm} \)
- \( \beta x^* = 100 \text{cm} \)

Specific Luminosity/bunch

\( [10^{30} \text{cm}^{-2} \text{s}^{-1} \text{mA}^{-2}] \)

\( l_{\text{bunch \ HER}} \times l_{\text{bunch \ LER}} \ [\text{mA}^2] \)

Simulation head-on

Simulation 22 mrad

3.06 bucket spacing

22 mrad crossing
Conservative, robust detector should handle ~20x more background.
Main challenge: R+D of a photon detector for operation in high magnetic fields (1.5T)

Candidates:
• MCP PMT: excellent timing, could be also used as a TOF counter
• HAPD: proximity focusing mode, problems with the stability
• SiPMs: easy to handle, but never before used for single photon detection (high dark count rate with single photon pulse height) → use a narrow time window and light concentrators

First Cherenkov photons observed with SiPMs!
How to increase number of photons w/o degrading resolution?
Use of radiator with increasing refractive ind. – focusing radiator

- both layers with the same $n$ - “normal” configuration
- rings overlap from different layers - “focusing” configuration
Aerogel RICH - test results

4cm aerogel single index

2+2cm aerogel

Marko Bračko
Rare decays - prospects

• Radiative, electroweak and tauonic B decays are of great importance to probe new physics.

• We are starting to measure $B \to \tau \nu$, $K\nu\nu$, $D\tau\nu$, $A_{FB}(K^*\Pi)$, $A_{CP}(K\pi^0\gamma)$ etc. at the current B factories.

$\rightarrow$ Hot topics in the coming years!

• For precise measurements, we need a Super-B factory!

$\rightarrow$ Observe $K^{(*)}\nu\nu$, zero crossing in $A_{FB}$, $D^{(*)}\tau\nu$

$\rightarrow$ Expected precision ($5ab^{-1} \rightarrow 50ab^{-1}$):
  - $\text{Br}(\tau\nu)$: $13\% \rightarrow 7\%$
  - $\text{Br}(D^{(*)}\tau\nu)$: $7.9\% \rightarrow 2.5\%$
  - $q_0^2$ of $A_{FB}(K^*\Pi)$: $11\% \rightarrow 5\%$
  - $A_{CP}(K\pi^0\gamma)\ tCPV$: $0.14 \rightarrow 0.04$
## SuperB vs SuperKEKB

### Notes:

- SuperB length w/o spin rotators.
- SuperKEKB luminosity assumes x2 gain from crab cavities.

SuperB luminosity arises from small emittance & small $\beta^*$ compared to SuperKEKB.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SuperB</th>
<th>SuperKEKB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference (m)</td>
<td>1800</td>
<td>3016</td>
</tr>
<tr>
<td>Energy (GeV) (LER/HER)</td>
<td>4/7</td>
<td>3.5/8</td>
</tr>
<tr>
<td>Current (A)/beam</td>
<td>1.85</td>
<td>9.4/4.1</td>
</tr>
<tr>
<td>No. bunches</td>
<td>1251</td>
<td>5018</td>
</tr>
<tr>
<td>No. part/bunches</td>
<td>$5.5 \times 10^{10}$</td>
<td>$12/5 \times 10^{10}$</td>
</tr>
<tr>
<td>$\theta$ (rad)</td>
<td>2x24</td>
<td>2x15</td>
</tr>
<tr>
<td>$\varepsilon_x$ (nm-rad) (LER/HER)</td>
<td>2.8/1.6</td>
<td>24</td>
</tr>
<tr>
<td>$\varepsilon_y$ (pm-rad) (LER/HER)</td>
<td>7/4</td>
<td>180</td>
</tr>
<tr>
<td>$\beta_y$ (mm) (LER/HER)</td>
<td>0.22/0.39</td>
<td>3</td>
</tr>
<tr>
<td>$\beta_x$ (mm) (LER/HER)</td>
<td>35/20</td>
<td>200</td>
</tr>
<tr>
<td>$\sigma_y$ (µm) (LER/HER)</td>
<td>0.039</td>
<td>1</td>
</tr>
<tr>
<td>$\sigma_x$ (µm) (LER/HER)</td>
<td>10/6</td>
<td>50</td>
</tr>
<tr>
<td>$\sigma_z$ (mm)</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>$L$ (cm$^{-2}$s$^{-1}$)</td>
<td>$1 \times 10^{36}$</td>
<td>$4 \times 10^{35}$</td>
</tr>
</tbody>
</table>
## Comparison between SuperB and SuperKEKB

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Emittance</td>
<td>$\varepsilon_x$</td>
<td>1.6</td>
</tr>
<tr>
<td>Horizontal beta</td>
<td>$\beta_x$</td>
<td>20</td>
</tr>
<tr>
<td>Vertical beta</td>
<td>$\beta_y$</td>
<td>0.3</td>
</tr>
<tr>
<td>Horizontal beam size</td>
<td>$\sigma_x$</td>
<td>5.7</td>
</tr>
<tr>
<td>Vertical beam size</td>
<td>$\sigma_y$</td>
<td>35</td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>6</td>
</tr>
<tr>
<td>Half crossing angle</td>
<td>$\phi_x$</td>
<td>17</td>
</tr>
<tr>
<td>Piwinski angle</td>
<td>$\phi$</td>
<td>18</td>
</tr>
<tr>
<td>Current (LER/HER)</td>
<td>$I_b$</td>
<td>2.28/1.30</td>
</tr>
<tr>
<td>Luminosity ($x10^{35}$)</td>
<td>$L$</td>
<td>10</td>
</tr>
<tr>
<td>AC Plug Power</td>
<td>$P$</td>
<td>34</td>
</tr>
</tbody>
</table>

One order magnitude smaller than SuperKEKB

AC power for KEKB is already 40 MW. Max site power is 100 MW at KEK.